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ELECTRICAL FLIGHT TECHNOLOGY- A SHORT REVIEW AND CHALLENGES

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ABSTRACT

Aircrafts are mainly powered by carbon-based fuels such as aviation gasoline or kerosene. But with the declining of oil resources and the increasing in the hydrocarbon emissions into the atmosphere by the aircrafts, the whole world especially the aviation industry is looking for an alternative power source. Also the aviation industry looks for aircraft that are much quieter and more fuel efficient than the aircrafts which are currently in use. This paper gives a brief review on the electrical flight technology. It also highlights the advantages as well as the challenges in the electrical flight technology.

KEYWORDS: Electrical Flight, e-flight, Battery & Solar Flight

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INTRODUCTION

Recent advancements in the aviation industry are more focused towards the electric propulsion technology. The interest in electric propulsion has grown considerably in the recent years. The emissions of hypersonic aircrafts are also minimized by using environmentally favorable fusion propulsion technology [1]. Electric micro propulsion system has also gained attraction with the development of micro space craft [3].

The growth of air traffic is increasing at a rapid rate which can be very well understood from the Figure 1 [40]. In turn this leads to the increase in the number of aircrafts which in turn leads to increase in the fuel consumption and it finally leads to a greater impact towards the environment. In spite of enormous amount of emissions and pollution, the oil prices are also increasing due to the depletion of the resources. Based on all these, the aviation industry is desperately looking for an alternate power source to reduce the fuel consumption. The main motivation for the Electrical flight came from the environmental impact on "HYDRO CARBON" burning aircrafts with its increase in gas emission and acoustics. Technology advancements in this technology flights will not only makes the flying cheaper but also reduces the green house emission impacts in the atmosphere. Data reveals that about 500 million tons of carbon dioxide is being released by aircrafts into the atmosphere representing a significant contribution to global warming. This technology replaces the petrochemical consumption which will be replaced by battery powered electricity[21].Attractive feature of electric propulsion is that there is zero emission while using it.

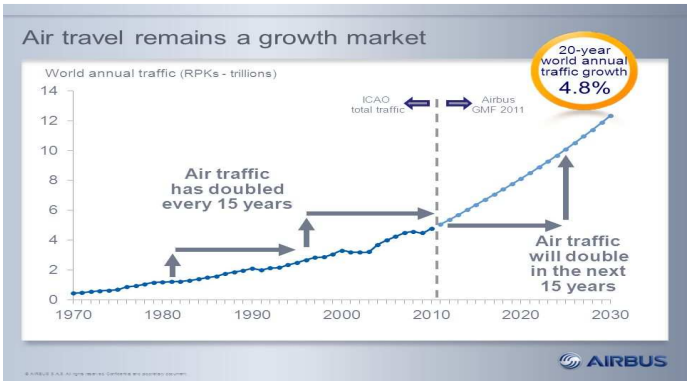

Figure 1: Air Traffic Growth Rate by AIRBUS

A SHORT HISTORY

Electrical flight is not a new technology. It dated back in the year 1883 when a French balloon pioneer Gaston Tissander, first used an electric motor in an airship. But this technology was not feasible for many years, because of the aircraft's sensitivity to mass. The electrical flight can be operated under two sets of technology.

- Battery powered electrical planes
- Solar powered planes

BATTERY POWERED ELECTRICAL PLANES

On 30th June, 1957, Col. H.J. Taplin of the United Kingdom, made the first electric powered radio controlled flight named "Radio Queen". But, no experiments were carried out in it.

In the early 1940's Fred Militky designed a model aircraft, with toy electric motors. But he could not obtain successful results because of the heavy brush motors and the lead batteries. Since then, gradual evolution took place in the field of electric flight with improvements in the motors and batteries. In the year 1951, photovoltaic technology started to bloom from the Bell Telephone Laboratoies. The first silicon photo-voltaic cell which is capable of converting the sun's energy to power was developed by Daryl Chapin *et.al* [24]. It was the time when Ni-Cd batteries with high power densities, started hitting the market. With the availability of these batteries, in the year 1972, Militky developed the first radio-controlled aircraft model [2]. Finally, using the same batteries he prepared the first manned electric aircraft, which was a modified motor glider MB-E1 and took the first flight on October 21st, 1973 by pilot H. Brditschka in Austria. Although, the first flight lasts only for about 15 minutes, it made a history by paving way for electric propulsion.

Antares 20E was launched in 2003 as the world's first electric powered production aircraft. It was manufactured by the Lange Aviation company in Germany. They also produced variants like Antares E23, which has a wing span of about 23m [25]. The concept of E-Genius emerged from Institute for Flugzeugbau. It successfully completed its first flight on 25th May 2011 in Mindelheim, Germany. On 15th June E-Genius made a flight over 340km, which was claimed to be the longest distance ever flown with an electric aircraft at that time [26]. The Italian light weight Silent 2 Electro is the only self-launching sailplane incorporating the Front-electric launcher/Sustainer (FES). Designed for the new FAI 13.5m class, every component of the glider is built to the very highest standard and everything is incredibly light [27]. In the year 2014, Ventus-2cxa, a high performance glider was built by Schempp-Hirth, with a Front electric sustainer electric motor system.

Previously, the company also produced sailplanes like Arcus, Discus and its variants, Duo Discus, Quintus etc. [28].

Elektra One is a one seater electric aircraft, manufactured by PC-Aero Gmbh Company. They also produced variants like Elektra Two, Elektra One Solar, Elekta One UAS etc., by making slight changes in their structure there, by improving their performances [29]. A French company by name, Electravia built BLE1 Electra; an electric powered open-cockpit airplane which took the first flight on 23rd December, 2007 became the world's first registered aircraft powered by an electric motor with batteries [30].

The Boeing Research and Technology Europe Team modified a two-seater Dimona airplane built by Diamond Aircraft Industries of Austria, with a Proton Exchange Membrane fuel cell/ Lithium-ion Battery hybrid system, to power an electric motor which in turn is coupled with a conventional propeller. After reaching the cruise altitude, the pilot disconnected the battery connection and maintained a level flight with a speed of about 60km/hr for 20 minutes with fuel-cell generated power alone. It is the remarkable achievements of the Boeing Research Team [31].

E-340 is a two-seater electric powered airplane manufactured by Yuneec International Co. Ltd. The 48kW electric propulsion system and the carbon fiber composite airframe are its unique features. Recognizing this achievement, the company was awarded with the Lindberg Electric Aircraft Prize. The company also manufactured another aircraft by name E-Spyder with innovative power drive 24 propulsion system which incorporates the motor, controller, 75 Volt batteries and a charger. In the year 2013, the aircraft received the world's first type certification for an electric aircraft from Deutschen Ultra leicht flug verbandes (DULV) [32].

Even the Airbus had made its debut entry into the electric propulsion era with its E-fan. On April 2014, E-fan made its first public flight and a year later it became the initial all electric airplane to cross over the English Channel completely on its own power. Following its successful flight, Airbus moved with an updated "plus" version which includes a hybrid-propulsion system [33].

Some Of Today's Electric Airplanes Are Listed In Table.1 [29,39].

Table 1: A few of today's electric airplanes

Specifications	Elektra One	Elektra One Solar	Elektra Two Record	Elecktra Two Standard	E340
Max. Take-off Weight	300 kg	300 kg	350 kg	350 kg	470 kg
Empty Weight	100 kg	100 kg	140 kg	200 kg	250 kg
Battery Weight	100 kg	100 kg	80 kg	Up to 100 kg	30 kg
Payload	100 kg	100 kg	150 kg	180 kg	177 kg
Wing Span	8.6 m	11 m	17 m	14 m/ 17 m	13.8 m
Wing Surface	6.4 m^2	8.2 m^2	19 m^2	15 m^2/ 19 m^2	11.37 m^2
Max. Engine Power	16 kW	16 kW	16 kW	40 kW	40 kW
Max. Range	More than 400 km	Upto 1000 km	More than 2000 km	14m wing span: 500 km 17m wing span: 700 km	227 km
Max. Endurance	More than 3 hours	More than 8 hours	Over 20 hours	14m wing span: 5 hours 17m wing span: 8 hours	2.5 hours
Cruise	160km/hr	140km/hr	80km/hr	14m wing span:140km/hr 17m wing span:120km/hr	90km/hr

Table 1: Contd.,					
Aspect Ratio	11.65	14.7	15	14m wing span: 13 17m wing span: 15	16.75
Best Glide Ratio	25	30	34	14m wing span: 28 17m wing span: 34	25
Certification	Ultralight-class-Germany	Ultralight-class-Germany (LTF-UL)	LTF-UL Germany	LTF-UL Germany	FAA

SOLAR POWERED PLANES

The first flight of the solar powered aircraft, Sunrise I, designed by R.J. Boucher took place on November 4, 1974. The endurance of the flight was about 20 minutes and it flew at an altitude of about 100m. It derived a power of about 450W from the 4096 solar cells installed [2]. In spite of its good inaugural flights, it underwent serious damages when flying through a sand storm. Sunsrise II, an improved version of the previous one was manufactured and put to test on September 12, 1975 [41]. In this version, the weight is reduced and the number of solar cells impinged is increased to 4480 to deliver a power output of about 600W. This version also encountered problems with the command and control systems. With all these, the solar flight came into picture. On the other hand, similar evolution came in Europe. On 16th August 1976, Fred Militky with his model Solaris had completed three successful flights of 150 seconds endurance and reached an altitude of 50m [41]. Since then the interest with solar energy airplane models increased among the airplane model builders. Even though, the initial flight lasted only for a few seconds, it gradually increased to minutes and then to hours.

In August 1996, David Beck in his Solar Solitude sets a record by achieving a range of about 38.84 Km and later also sets a record in reaching an altitude of about 1283m [34]. Later on, Wolfgang Schaeper with his Solar Excel had mastered in all the categories i.e. in duration(11h34m18s), distance in a straight line (48.31km), gain in altitude (2065m), speed (80.63 km/hr), distance in a closed circuit (190 km) and speed in a closed circuit(62.15 km/hr) from 1990 to 1999 [35].

By seeing the innovations in the solar model airplanes, in the late 70's, the pioneers got interested in manned solar powered aircrafts. Even though aircrafts like Solar one and Solar Riser was made as the first manned solar powered aircraft; it was not able to make any landmarks in the history. Dr. Paul B. McCready, along with Aero Vironment company and R. J. Boucher, designer of Sunrise I and II receiving the sponsorship from The Dupont Company, designed Gossamer Penguin, which took flight on 18th May 1980 with 3 years old Marshall on board was considered as the *world's first piloted solar powered aircraft.* Even though it set a world record, it had some altitude limitations. Because of this, they came up with a new design, which is the Solar Challenger with 16,128 solar cells, which produce a power output of about 2500W. It made its first flight on July 7th, 1981 covering a range of about 262.3 km and an endurance of 5 hours and 23 minutes with no onboard energy storage system.

Simultaneoulsy, in Germany, a designer named Gunter Rochelt had built Solair I, with 2499 solar cells which produced a power of about 1800W. It had used mostly the solar energy and the thermals to cross the English Channel in 5 hours and 41 minutes. In the year 1986, US based designer Eric Raymond designed Sunseeker.

After all these developments, the researchers and the designers started to think about the long range and long endurance solar powered aircrafts. As a result of this, Pathfinder came into picture and made its maiden flight in 1993. In 1995, it broke the solar challenger's record by reaching an altitude of about 50,500ft and later achieved 71,530ft after

two years. It has been upgraded to a new version, Pathfinder plus with slight changes in the structure.

Centurion is a light weight, solar power, remotely piloted flying wing aircraft designed for long duration high altitude flight. Its main motto is to be used in scientific sampling and imaging missions or to be used as relay platforms in telecommunication [36]. With the sensors and other equipment need for scientific study it can reach upto an altitude of about 80000ft. Lithium batteries were used to store the energy but it was not sufficient for the night flight.

To overcome the limitations encountered with centurion, AeroVironment Inc. designed Helios as the ultimate solar aircraft that can offer virtually eternal flights in the stratosphere. It will store upto two-thirds of the energy received to maintain its altitude overnight. It attained an unofficial world –record altitude of about 96,863ft in 2001. Unfortunately, due to structural failure it fell into the Pacific Ocean on June 26, 2003 [41]. Numerous other research and study are still carried out with Solitair, Helipat and Shampo funded by European program [11, 7].

On 3rd June 2005, Alan Cocconi, in his 2nd attempt with Solong attained an endurance of about 48hours and 16 minutes which took place in California's Colorado Desert. Zephyr, another solar powered aircraft, manufactured by a British Company named QinetiQ has set a world record for longest duration unmanned flight with a 54 hour flight on 10th September 2007 reaching an altitude of 58,355ft [37].

Solar Impulse 2 has completed the first round-the-world flight by a solar-powered aero plane. The plane, which has a wingspan wider than a Boeing 747 and carries more than 17,000 solar cells on its wings, began the circumnavigation in March 2015 in Abu Dhabi. It has crossed both the Pacific and Atlantic Ocean using no fossil fuel and has spent more than 23 days in the air. During daylight, the solar panels charged the plane's batteries, which make up a quarter of the craft's 2.3 tons weight. The pilot also climbed to 29,000 feet during the day and glided down to 5,000 feet at night, to conserve power. The plane flies at about 30mph, although it can go faster if the sun is bright. The aim of the Solar Impulse adventure was not to develop solar-powered planes for widespread use, but to show the capabilities of renewable energy [38].

GENERAL PROPULSION SYSTEMS

Today's fuel is mainly based on oils which can be thermally decomposed. With the help of piston engines or gas turbine engines, these fuels are burnt to produce the mechanical power. The main thing to be noticed with these fuels is that when they are burnt, the exhaust is being emitted into the atmosphere which in turn affects the environment. Also the fuel consumption during flight creates a change in mass of the aero plane thereby reducing the aircrafts performance.

ELECTRICAL POWER SOURCE

Electrical power can be generated by means of using "liquid polymer ionic batteries" which gives double the power of normal liquid ion batteries which we use in day to day world. These batteries are less in weight and also increase the energy saving[19]. The electrical power source can also be approached in hybrid method by means of when the battery is running out of power, two small jet fuel burning turbines can be placed in order to propel the aircraft. Apart from this, lithium ion batteries can also be used for the driving of electrical propelled engines. In electrical propulsion systems, battery based and fuel cell based seems to be the two main areas of interest [17].

The main idea of electrical propulsion is to reduce the weight of aircraft, and pollution caused by jet propulsion. Hanging up of two to four jumbo jet engines under the wing can be easily replaced by small and lighter electrical driven

fans or propellers [20]. This small fans or propellers can be placed at different areas of the aircraft which does not affect the aerodynamics of the aircraft and drag also gets reduced in the wing area.

FUEL CELL BASED SYSTEMS

A fuel cell is an electrochemical device that converts hydrogen directly into electricity and heat with none of the products of combustions such as carbon-di-oxide. Other than heat, water is its only exhaust. The purpose of the fuel cell is to produce an electrical current that can be directed outside the cell to do work such as powering an electric motor.

BATTERY SYSTEMS

In battery systems, the electric power is directly extracted from the energy stored in the batteries. The efficiency is limited by the chemical processes occurring during charging and discharging. Except for some specific air breathing lithium di oxide cells, the mass of the system is not usually changing.

Nowadays, most of the electric powered aircraft are using Lithium-Ion type battery systems. This is because of the availability of those systems in huge number as the main power source for mobile devices and also the cheap cost. The current system can provide a mass energy of upto 200 Wh/kg. But, this is not sufficient for automotive and large aerial vehicles. This had led to the advanced study in the Lithium based systems. Due to this, Lithium-Sulphur and Lithium-Oxygen became the main research area for the Scientists. The former reached a prototype level while the latter is in the infancy state.

ADVANTAGES OF E-FLIGHT TECHNOLOGY

The main advancement is that it results in lowering the cost of manufacturing of an aircraft, when the cost of making electrical motors and power circuits gets reduced. If this flight technology is incubated, the cost of flying also gets cheaper and it also reduces the pollution in the environment by limiting the reduction of greenhouse gas into the atmosphere. Jet acoustics (NOISE) produced by the aircraft gets reduced[22].Unlike internal combustion engines it does not need air to produce power so that they can retain their full power even at high altitudes. It only requires a shorter runway to takeoff when compared to jet propelled aircrafts. If this flight gets incorporated, flying gets cheaper and it will be economical for the passengers flying in it. Also, the electric motor need no warm-up time. Rapid recharging is possible than refueling. Even the maintenance or overhauling cost for internal combustion engines is much more costly than the electric motors.

CHALLENGES OF E-FLIGHT

Flying requires extra-ordinary amount of energy and doing so under electric power requires at least one massive leap forward in the battery technology. The aircrafts need a lot of energy during take-off than the cruise. Battery storage is the key limiting factor for electric aircraft. Battery development is a highly complex, expensive and risky job. Today's Lithium-Ion batteries have the maximum energy density of about 1million joules of energy per kilogram whereas aviation fuel produces about 43milion joules of energy per kilogram. In simple words, 1000 pounds of jet fuel yields about 14 times more energy than a 1000 pounds battery. Also the batteries are so heavy. So, swapping of fuel tanks with batteries makes the weight to increase further. In short, a battery does not offer the power to weight ratio. Also, in case of delayed landing the planes need to have extra fuel to sustain flight. Even the airports need to have recharging ports which is a bit expensive.

ADVANCEMENTS WHICH CAN BE INTRODUCED

Superconductors can be used as an alternative for conventional electrical machines which are too heavy [10]. In superconductors the motor is used to drive the propeller and the generator is used to power the load. Battery power capacity can be increased for long range flights if incorporated [23]. The weight of the batteries can be reduced with increase in storage capacity.

CONCLUSIONS

Electric aero propulsion paves way for new concepts in the aircraft design technology that are quieter and much more energy efficient, thereby creating a revolution in the aviation industry. Currently, there is a lot of development in the battery technology. But, the main problem is that the researchers or the Scientists need to work along with the industry professional so that they can apply their new ideas in the real time scenarios through which they can identify problems to get the best output. When such collaboration happens, it will bring many new innovations in the industry.

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